EQUIPMENT FOR DETERMINING THE FLOW PROPERTIES OF GRANULAR AND POWDERING MATERIALS

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ABSTRACT: The process of mixing, transporting and storing solid particles (granular and powdery materials) is very complex, depending not only on the properties of the particles (density, size, particle size distribution, shape, surface properties), but also on the differences between the particle properties of the components involved. in these operations. In order to perform these operations in good conditions, it is very important to know the properties of the materials involved. For example, in mixing operations it is very important to know how to select the right equipment for a particular application or for transport operations how to choose the right variant for a certain type of granular material. In this paper are presented some solutions for determining the properties of granular and powdery materials, leading to an optimization of the choice of methods for performing operations.

KEYWORDS: granular, powder, flow, friction, flope, kinetic

1. INTRODUCTION

In the mechanical, chemical, pharmaceutical, food industries, granular or powdery materials are frequently worked on. Within these industries there are also storage, packaging, transport operations, which are based on the flow phenomenon of these materials.

A classification of these granular materials comprises two classes:
-granular (coarse);
-powders.

Granular materials are in turn classified according to their mobility, in which the shape of the particles is the classification parameter. Otherwise, in the case of Jenike powders, the flow function defined as follows is used as a classification criterion [1]:

$$F_F = \frac{\sigma_1}{f_c} \qquad [1]$$

where:
- σ_1 - consolidation effort;
- f_c - the disintegration effort and has the significance of a resistance that the solid opposes to the flow.

Powdery materials can be divided into [1]:
- materials that do not flow, under the influence of very high cohesive forces, $F_f < 2$;
- materials in which relatively high cohesive forces appear, $2 < F_f < 4$;
- easily flowing materials, $4 < F_f < 10$;
-free flowing materials $F_f > 10$.

2. EQUATIONS OF FLOW OF GRANULAR AND POWDERY MATERIALS

The flow of granular materials can be described with the differential equations of fluid flow:
- continuity equation;
- impulse transfer equation;
- rheological equations.

The free flow of granular powders and materials through funnels and bunkers depends mainly on the following parameters: material granulation, friction angle, natural slope angle and kinetic angle.

A set of granules may contain granules of the same size or different sizes. The size of a granule is expressed by the equivalent diameter or average diameter. The equivalent diameter of a granule is the diameter of the sphere with the same volume as that of the granule and is calculated by the relation [1]:

$$d_{equivalent} = 1{,}24\sqrt[3]{\frac{m_g}{\rho}} \quad [2]$$

and the average diameter is determined by one of the relations:

$$d_m = \frac{L+l+h}{3} \quad [3]$$

$$d_m = \sqrt[3]{L \cdot l \cdot h} \quad [4]$$

$$d_m = \frac{\sqrt{2(L \cdot l + l \cdot h + L \cdot H)}}{6} \quad [5]$$

where:
- m_g - mass of the granule;
- ρ - density of the granule material;
- L, l, h - granule dimensions.

In the case of a set of granules of different sizes, the average diameter of the granules can be determined on the basis of particle size analysis, using the relation:

$$d_m = \frac{1}{100} \cdot \sum_{i=1}^{n} \frac{d_i + d_{i+1}}{2} \cdot q_i \quad [6]$$

where:
- d_i - the size of the sieve spaces on which the material remained;
- d_{i+1} - the size of the sieve spaces through which the material passed;
- q_i - mass of the class in relation to the total mass of the analyzed material.

3. PARAMETERS OF FREE FLOW OF GRANULAR AND POWDER MATERIALS

3.1. Friction angle

The angle of friction is the angle of inclination of any surface until the particles begin to slide. It can be measured by the inclined plane method. The friction angle can be calculated with the relation [1]:

$$tg\ \varphi = \frac{0{,}211}{z^2} + 0{,}3436\left(\frac{\varepsilon}{d}\right)^{0{,}5} - 0{,}0171 \cdot \rho + 0{,}1834 \quad [7]$$

where:
- d - average particle diameter;
- z - form factor;
- ε - surface roughness index;
- ρ - density of the material;

3.2. The natural slope angle

The natural slope angle is the angle formed by the generator with the base of the cone which is obtained by dropping a granular material on a horizontal flat surface (fig.1). It is calculated with the relation [1]:

$$tg\ \propto = \frac{2h}{d} \quad [8]$$

where:
- h - height of the material cone;
- d - diameter of the material cone.

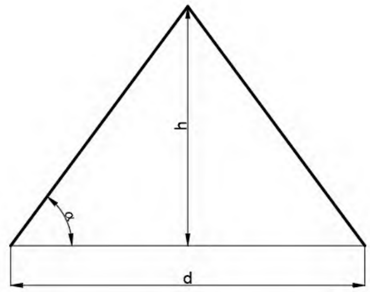

Fig. 1. *Natural slope angle*

3.3. The kinetic angle

The kinetic angle is the angle it makes with the horizontal surface of the material introduced into a rotating tank (fig.2).

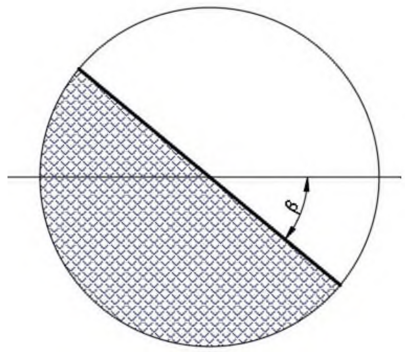

Fig.2. *The kinetic angle*

4. PRESENTATION OF WORK EQUIPMENT

4.1. Equipment for determining the friction angle

For the purpose of the experimental determination of the friction angle, the equipment represented in figure 3 is used [2].

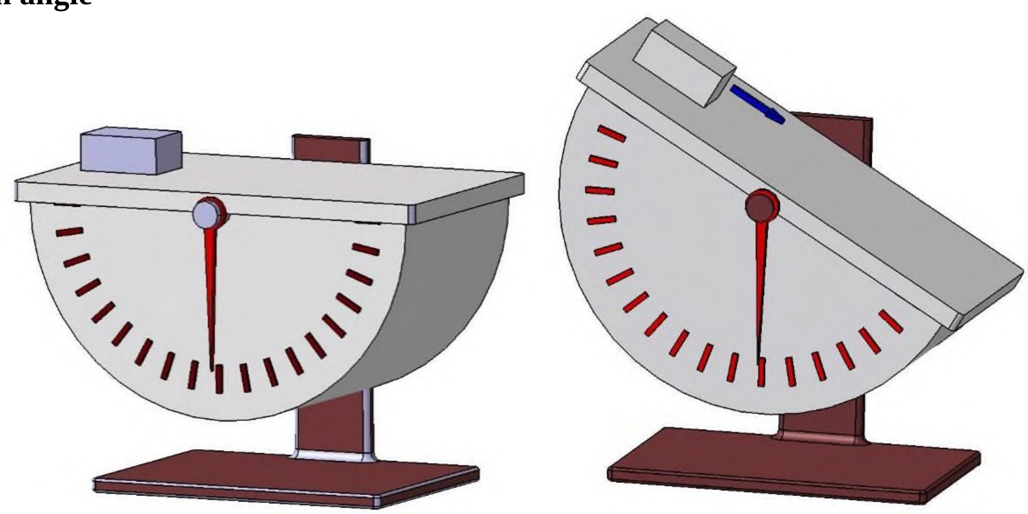

Fig.3. *Equipment for determining the friction angle*

The equipment consists of a rotating half-cylinder around an axis, provided at the top with a removable plate made of ordinary steel against which the friction angle is determined. On the front, the equipment has a graduated scale and an indicator needle that will remain upright regardless of the angle of inclination of the steel plate. The test material is placed on the plate. Measure the angle at which the test material begins to slide on the plate [2].

4.2. Equipment for determining the natural slope angle

The apparatus consists of a feeding funnel arranged in a vertical position, at the bottom having a taper that allows the granular material to be directed to an outlet. The funnel has a plate with a known diameter d mounted inside, which will retain the granular material subjected to subsequent measurements. The granular material can be collected in the funnel or can be discharged by means of a stop which can be translated, obstructing or uncovering the discharge part of the funnel. The funnel is mounted on a flat surface, which in turn is mounted on a support. A tank is placed inside the support in which the excess granular material drains from the funnel (fig.4).

For the measurement, position the stopper in the "closed" position and pour granular material into the funnel until it is completely filled. The stop is then placed in the "open" position, the granular material flowing from the funnel into the excess material tank. A cone of granular material will remain on the plate and by measuring the values H1 and H2 the formula [7] is applied [3].

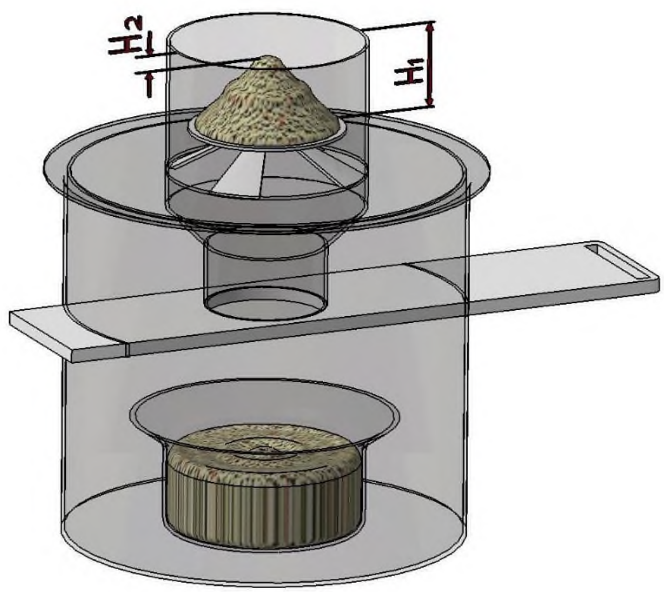

Fig.4. *Equipment for determining the natural slope angle*

4.3. Equipment for determining the kinetic angle

The equipment consists of a cylindrical tank mounted in a horizontal position inside which the granular material is inserted [4][5]. An indicator needle and a graduated scale are mounted on the front of the tank. The tank in which the granular material was inserted rotates around an axis with a certain speed, the granular material being in turn driven in this movement and tilting with respect to the horizontal with an angle that will be ensured on the graduated scale (fig.5) [6][7] . This is the kinetic angle.

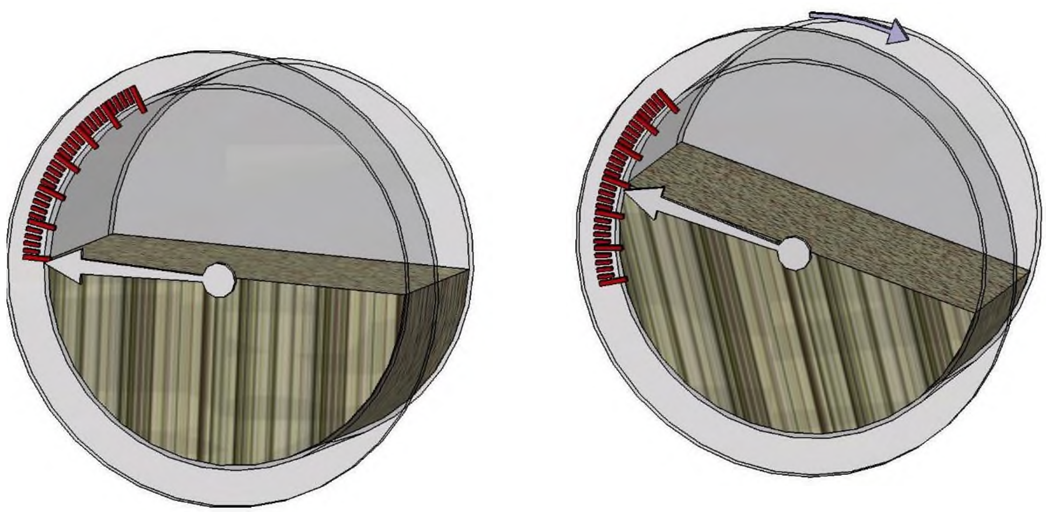

Fig.5. *Equipment for determining the kinetic angle*

5. EXPERIMENTAL DATA REGISTRATION

Experimental data are obtained by direct determinations. For the friction angle (φ_1, φ_2) two steel plates with different roughnesses will be used (R_{z1} and R_{z2}), for the natural slope angle the heights H_1 and H_2 will be measured and for the kinetic angle the inclination angle α of the surface of the granular material will be measured. The data will be recorded in a table (table 1).

Table 1. *Measured quantities*

Nr.crt.	Granular material	Measured quantities					
		φ_1	φ_2	H_1	H_2	d	α
1	...						
2	...						
...	...						

6. CONCLUSIONS

The process of mixing, transporting and storing solid particles (granular and powdery materials) is very complex, depending not only on the properties of the particles (density, size, particle size distribution, shape, surface properties), but also on the differences between the particle properties of the components involved. in these operations. In order to perform these operations in good conditions, it is very important to know the properties of the materials involved. For example, in mixing operations it is very important to know how to select the right equipment for a particular application or for transport operations how to choose the right variant for a certain type of granular material.

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